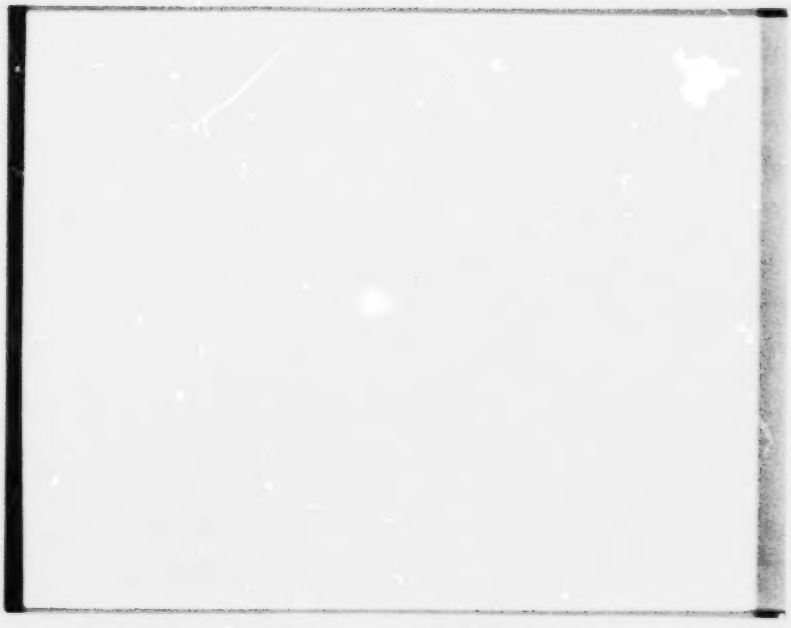
MINERALS

ECONOMIC & REGIONAL DEVELOPMENT AGREEMENT



Canada

Manitoba

MC-13087A

Work on this project was conducted under the auspices of the Canada Centre for Mineral Technology, Energy, Mines & Resources Canada, funded as part of the Manitoba Mineral Development Agreement.

DSS FILE NO. 03SQ.23440-5-9246

DSS CONTRACT NO. 23440-5-9246/01-SQ

CANMET SCIENTIFIC AUTHORITY P.A. ANDREWS

UPGRADING OF FELDSPAR

MANITOBA MDA

Final Report by:

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TANTALUM MINING CORPORATION OF

CANADA LIMITED

MICROMEDIA

35pp

EXECUTIVE SUMMARY

ES1 Reject from the heavy medium separation spodumene preconcentration section at the Tantalum Mining Corporation's Bernic Lake mine has a high feldspar content and is a potentially valuable by-product. Market studies carried out had indicated that a minimum of 10% K_2O would be required to maximize the value of the product.

ES2 Various mineral processing techniques have been evaluated to determine the optimum treatment route to ensure that the minimum grade specification can be obtained at maximum recovery and minimum cost.

ES3 Further gravity concentration, electrostatic separation, magnetic separation and flotation were all considered. Optimization of the existing heavy medium plant will enable the minimum specification to be met at minimal cost. Considering the efficiency of succeeding spodumene flotation circuits, it is recommended that the heavy medium plant be operated to obtain a final feldspar product grading 10% K_2O, rather than maximum rejection of feldspar from the spodumene plant.

ES4 Flotation will maximize final grade but at the expense of recovery. Even with thorough reagent removal by acid washing the final product is slightly discoloured, such discolouration being exacerbated by heating.

ES5 Electrostatic separation is impractical, whilst magnetic separation would only be required to control any iron added during processing, as the iron content of the heavy medium reject is less than 0.04% Fe_2O_3.

ES6 The simplest, most cost effective and highest yield method of ensuring that specification grade is achieved is, therefore, close control of the existing heavy medium circuit.

ES7 Production of a marketable feldspar product therefore requires only a simple dry grinding/classification circuit. It is recommended that stabilization of product grade is controlled by maintaining a sizeable stockpile of heavy medium reject prior to the grinding plant. It is further recommended that grinding testwork be carried out by equipment manufacturers to size the equipment to suit the capacity and product size indicated in the market study.

SOMMAIRE EXECUTIF

ES1 Les rejets de la séparation du médium-concentré de spodumène provenant de la section préconcentreé de la mine Tantalum Mining Corporation Bernic Lake ont un contenu élevé de feldsparth et ont également un potentiel d'un produit secondaire de valeur considérable. Les études de marché effectuées indiquaient qu'un minimum de 10% K_2O serait requis afin d'attribuer une valeur maximale à ce produit.

ES2 Différentes techniques de traitement minéral ont été évaluées afin de déterminer le traitement optimum afin d'assurer que le niveau de spécification minimum soit obtenu par un recouvrement maximale et à coût réduit.

ES3 Entre autre, des concentrations de gravité, des séparations électrostatiques ainsi que des séparations et flotations magnétiques furent toutes considérées. Optimaliser le plant médium-concentré existant permettra d'accomplir la spécification minimale à un coût modique. Tenant compte du coefficient de rendement des réussites des circuits de flotations de spodumène, il est recommandé que le plant médium-concentré soit en opération afin d'obtenir un produit final de feldsparth avec un niveau de 10% K_2O, au lieu d'un rejet maximum de feldsparth du plant de spodumène.

ES4 Les flotations maximiseront un grade final mais aux dépens du recouvrement. Même en enlevant les réactifs par un lavage acide, le produit final est légèrement décoloré, telle décoloration étant exacerber par la chaleur.

ES5 La séparation électrostatique est impraticable tandis que la séparation magnétique serait seulement requis afin de contrôler tout fer ajouté pendant le traitement étant donné que le contenu global du fer dans les rejets medium-concentré est inférieur à 0.04% Fe_2O_3.

ES6 La méthode la plus simple qui tiendrait compte du coût effectif et qui donnerait un rendement supérieur s'assurant que le grade de spécification soit obtenu, donc, un contrôle sévère du circuit médium-concentré qui existe présentement.

ES7 La production d'un produit de feldsparth pouvant être placé sur le marché requiert simplement un circuit de classification/meulage à sec. Il est recommandé que la stabilisation du grade du produit soit contrôlé en maintenant un montant considérable de stocks de réserve des rejets médium-concentré avant l'acheminement au plant de meulage. Par ailleurs, il est recommandé que les expériences de meulage soient effectuées par les produits manufacturiers afin de vérifier l'équipement pour y attribuer la capacité et la dimension du produit indiqué dans l'étude du marché.

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INTRODUCTION

The Tantalum Mining Corporation of Canada Limited (Tanco) mines and processes ore from the complex pegmatite orebody at Bernic Lake, approximately 150 km. northeast of Winnipeg, Manitoba.

The zoned pegmatite which has been the subject of several major geological studies (e.g. 1-3) was, from its original discovery in 1929, sporadically mined for its tin, beryl, cesium and lithium potential. In 1967, Tanco constructed a 500 td^{-1} mill for tantalum processing and this operated until the end of 1982 at which time the operation was suspended due to adverse market conditions.

Tanco had also been considering exploitation of its 7M tonne reserve of spodumene, a lithium aluminum silicate. In 1984 with the assistance of a grant from the Enterprize Development Program of the Federal Government of Canada, Tanco commenced a pilot plant operation to develop both processes and markets. This pilot plant operation was sufficiently encouraging for Tanco to construct, in 1985-6, a dedicated 300 td^{-1} spodumene concentration facility alongside the still dormant tantalum plant. Incorporated in the flowsheet (Fig. 1) of this new concentrator is a heavy medium separation stage to preconcentrate the spodumene by the rejection of the lighter feldspathic minerals, primarily the potassium feldspar, microcline (4).

Considering the potential grade of this material, a market survey was commissioned and funded by the Canada-Manitoba Mineral Development Agreement, and research carried out, also funded by the Agreement, to determine the optimum route for producing marketable grades of potassium feldspar.

FEEDSTOCK

The heavy medium plant commenced operation on a continuous basis late June 1986, and daily analysis of the alkali content of the heavy medium reject commenced July 1, 1986. The average grade of the reject between July and December 1986 is shown in Table No. 1.

TABLE NO. 1

Average grade of Tanco heavy media reject

	Grade %	
K_2O	9.58	± 1.12
Na_2O	1.98	± 0.3
Li_2O	0.35	± 0.08

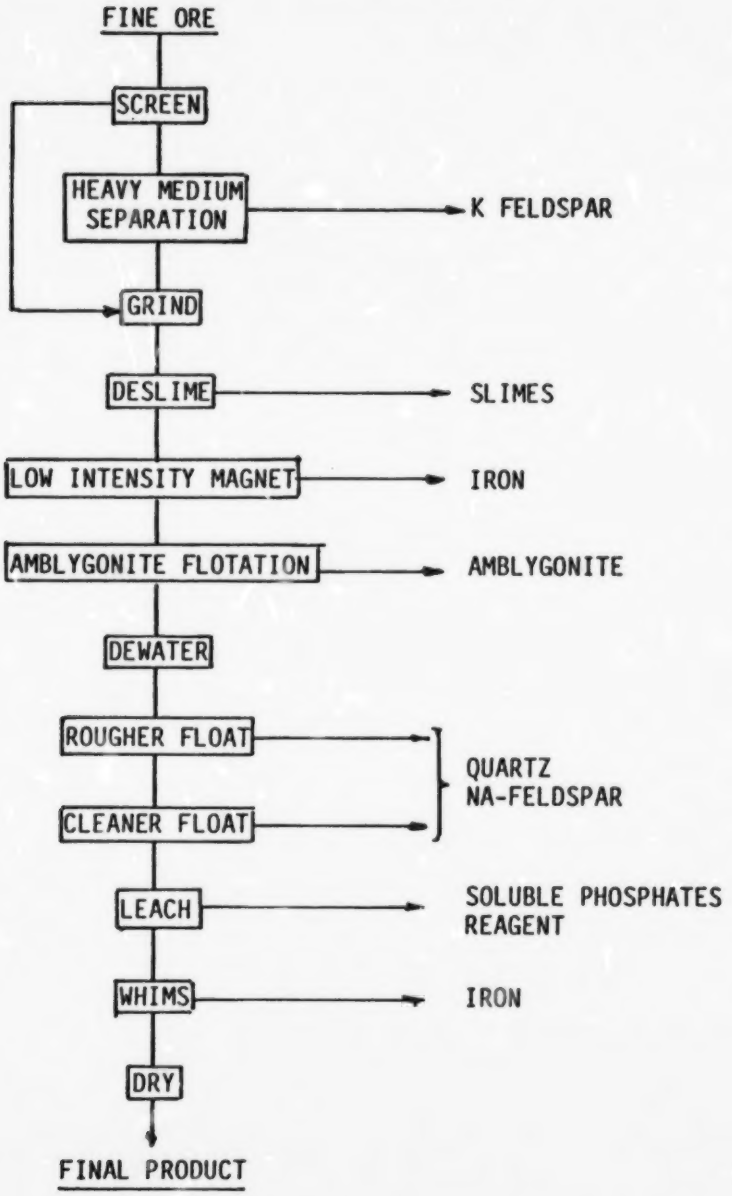


FIG. 1 NEW PLANT SCHEMATIC FLOWSHEET

The day by day data show some variation from this average, and daily plots of each of the above are shown in Fig. 2 (a, b, c). Apart from a short period, the grade is generally in excess of 9% K_2O and does, on many occasions, exceed 10% K_2O.

In order to get a more complete picture of the elements present in the Feldspar three special composites of plant Feldspar reject were collected and subjected to a full analysis. These data are detailed in Table 2.

TABLE NO. 2

Date	Li_2O	NaO_2	K_2O	Fe_2O_3	Al_2O_3	MnO_2	Rb_2O	P_2O_5	Cs_2O
19.1.87	0.37	1.93	9.73	0.021	17.2	0.014	1.69	0.45	0.57
20.1.87	0.37	2.25	8.82	0.021	16.4	0.011	1.48	0.62	0.60
21.1.87	0.24	1.84	10.22	0.024	16.6	0.009	1.73	0.57	0.63

TABLE NO. 3

Typical mineralogical distribution of h.m. reject (July-Sept. 1986)

Spod/Squi	1.5%
Quartz	4.5%
K-Feldspar	84.0%
Na-Feldspar	9.0%
Aplite	1.0%
	100.0%

Size analysis of the feedstock, which is controlled by the requirements for the heavy medium plant, is -12 +0.5mm and typically the moisture content of the reject is 6-8% H_2O.

MARKET STUDY REVIEW

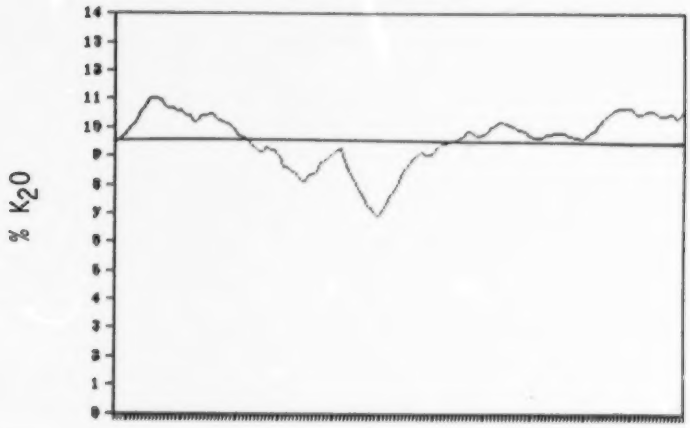
The Market Study, carried out by Agricola Mineralia (5) included analysis of a typical sample of heavy medium reject and generally confirmed Tanco's average analyses of the material. The study indicated that the product contains approximately 4% free silica, the removal of which would be advantageous to achieve full market acceptance at a premium price.

Commercially available potash feldspars contain between 10-11% K_2O with no rubidium. Tanco's heavy medium reject compared favourably with this; Agricola Mineralia's analysis gave a combined K_2O + Rb_2O assay of 10.89%.

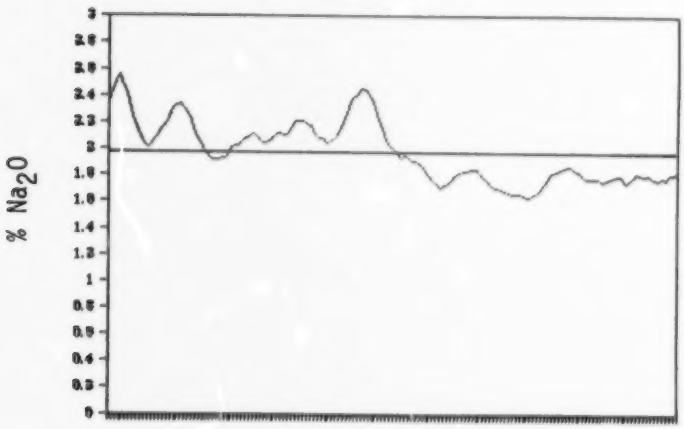
Sufficient markets would be available for Tanco to sell all of it's product in North America.

Fig. 2 Daily Alkali Content of Heavy Medium Reject

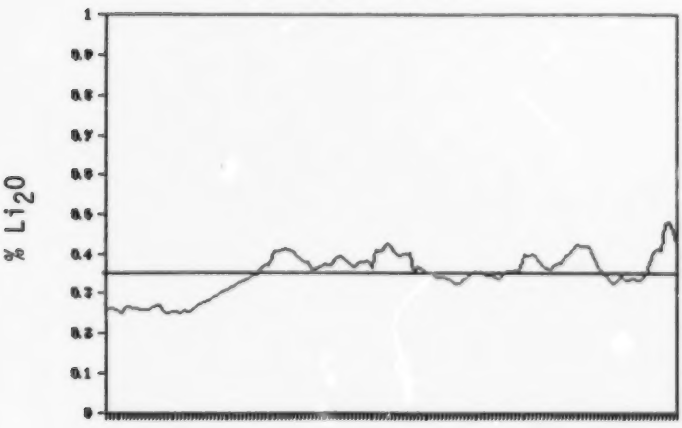
a) K20 Grade



b) Na20 Grade



c) Li20 Grade



RESEARCH PROGRAM

It had been assumed at the commencement of the research project that a significant improvement to the quality of the heavy medium reject would be required, presumably by flotation to achieve a marketable product containing over 12% K_2O. However, the market survey (as well as direct customer contact since) has shown that the amount of upgrading, if any, would be limited and would depend on the possible increased value of the enriched product compared with the cost of such upgrading.

The planned research project, initiated in May 1986, was therefore significantly modified to take account of the lower grade required for market acceptance of the project.

Various possible approaches to upgrading the heavy medium reject were examined. These included gravity concentration, electrostatic separation, magnetic separation, selective grinding and flotation.

Gravity Concentration

To determine the Potential of utilizing further gravity concentration to improve the quality of the product, heavy liquid analysis of a typical h.m. reject product was carried out, utilizing sequential analytical techniques described by Burt (6).

Results, based upon the main element of interest (K_2O) is shown in Table No. 3, and those for the auxilliary minerals (Li_2O, Na_2O) in Table Nos. 4 and 5.

TABLE NO. 3

HEAVY LIQUID ANALYSIS OF H.M. REJECT
Based on potassium assays

	FLOATS						SINKS		
	WEIGHT		ASSAY		DISTRIBUTION		WEIGHT	ASSAY	DIST
	%	cum %	%	cum %	%	cum %	cum %	cum %	cum %
-2.55	0.29	0.29	8.66	8.66	0.29	0.29	100	8.70	100.00
+2.55-2.60	5.7	5.99	13.61	13.37	8.92	9.20	99.71	8.70	99.71
+2.60-2.65	57.61	63.6	12.85	12.90	85.08	94.29	94.01	8.40	90.80
+2.65-2.70	32.27	95.87	1.39	9.03	5.16	99.44	36.4	1.37	5.71
+2.70-2.75	2.82	98.69	1.15	8.80	0.37	99.81	4.13	1.18	0.56
+2.75-2.80	0.44	99.13	0.83	8.76	0.04	99.86	1.31	1.23	0.19
+2.80-2.85	0.43	99.56	1.95	8.74	0.10	99.95	0.87	1.43	0.14
+2.85	0.44	100	0.93	8.70	0.05	100.00	0.44	0.93	0.05
	100.00		8.70		100.00				

TABLE NO. 5

HEAVY LIQUID ANALYSIS OF H.M. REJECT
Based on lithium assays

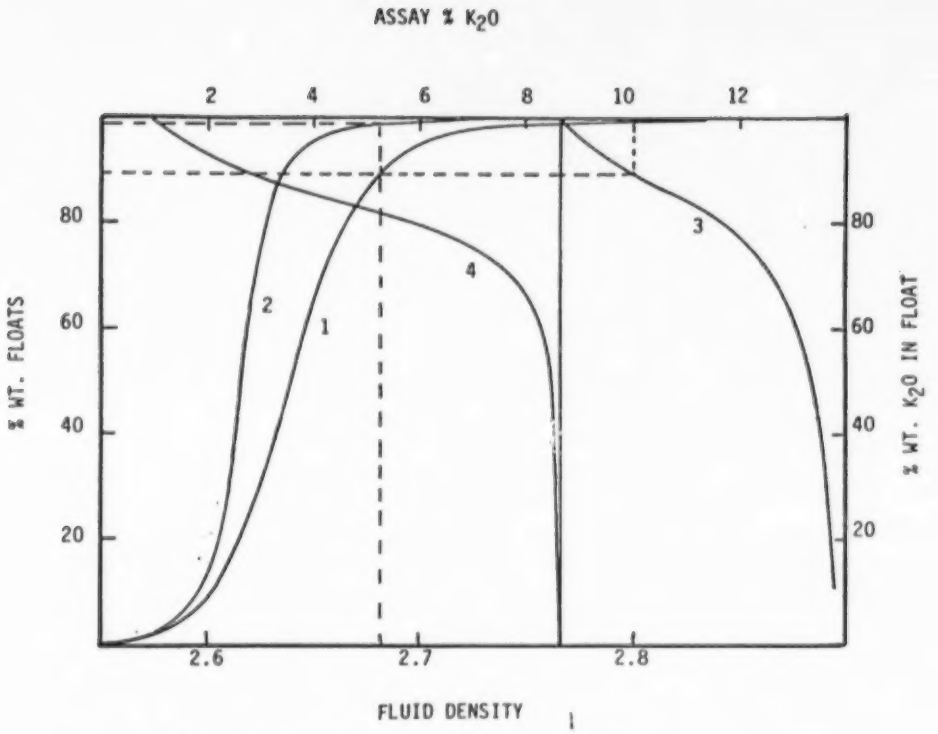
	FLOATS						SINKS		
	WEIGHT		ASSAY		DISTRIBUTION		WEIGHT	ASSAY	DIST
	%	cum %	%	cum %	%	cum %	cum %	cum %	cum %
-2.55	0.29	0.29	1.49	1.49	1.83	1.83	100	0.24	100.00
+2.55-2.60	5.7	5.99	0.09	0.16	2.18	4.01	99.71	0.23	98.17
+2.60-2.65	57.61	63.6	0.11	0.11	26.89	30.91	94.01	0.24	95.99
+2.65-2.70	32.27	95.87	0.25	0.16	34.24	65.14	36.4	0.45	69.09
+2.70-2.75	2.82	98.69	1.37	0.19	16.40	81.54	4.13	1.99	34.86
+2.75-2.80	0.44	99.13	2.1	0.20	3.92	85.46	1.31	3.32	18.46
+2.80-2.85	0.43	99.56	2.84	0.21	5.18	90.64	0.87	3.94	14.54
+2.85	0.44	100	5.01	0.24	9.36	100.00	0.44	5.01	9.36
	100.00		0.24		100.00				

TABLE NO. 6

HEAVY LIQUID ANALYSIS OF H.M. REJECT
Based on sodium assays

	FLOATS						SINKS		
	WEIGHT		ASSAY		DISTRIBUTION		WEIGHT	ASSAY	DIST
	%	cum %	%	cum %	%	cum %	cum %	cum %	cum %
-2.55	0.29	0.29	1.41	1.41	0.17	0.17	100	2.46	100.00
+2.55-2.60	5.7	5.99	1.61	1.60	3.74	3.90	99.71	2.46	99.83
+2.60-2.65	57.61	63.6	1.76	1.74	41.28	45.18	94.01	2.51	96.10
+2.65-2.70	32.27	95.87	3.9	2.47	51.24	96.42	36.4	3.70	54.82
+2.70-2.75	2.82	98.69	2.5	2.47	2.87	99.29	4.13	2.13	3.58
+2.75-2.80	0.44	99.13	2.36	2.47	0.42	99.71	1.31	1.34	0.71
+2.80-2.85	0.43	99.56	1.18	2.47	0.21	99.92	0.87	0.82	0.29
+2.85	0.44	100	0.47	2.46	0.08	100.00	0.44	0.47	0.08
	100.00		2.46		100.00				

The washability curves indicated that it is theoretically possible to enrich the feldspar to over 13% K_2O, albeit at a relatively low yield of 60%. Conversely a grade of 10% K_2O could theoretically be achieved, with a yield of 89% and K_2O recovery of 98% at a density specific gravity of separation of 2.68 Kg. L^{-1}. However, it can be seen that over 90% of the material reports to the 2.68 +/- 0.05 kg. L^{-1} range and practical gravity separation even by further heavy medium separation is impossible.



Line 1 Cumulative weight float vv density
2 Cumulative weight K_2O in float vv density
3 Cumulative assay floats vv weight
4 Cumulative assay sinks vv weight

Fig. 3 Washability Curves

However, these results indicate that, if the original separation in the Triflo separators were improved, then specification grades may be achieved in the main heavy medium plant. In fact, it can be seen from Fig. 2, that with experience of operation in the main plant the K_2O grade of the h.m. reject has improved and currently runs in excess of 10% K_2O.

Electrostatic Separation

Electrostatic separation of feldspar from quartz is technically possible using a free fall type separator (7); whilst such separations have been carried out in closely controlled atmospheres in the laboratory it has not been possible to develop a practical separation for pilot plant or industrial scale (8).

Consequently it was decided that there would be no practical value in testing this potential route.

Flotation

Summary

Flotation was tested as a possible way to upgrade feldspar, a by-product from the dense-medium plant, to a commercially acceptable material. The K_2O content of the flotation concentrate was used as a measure of the efficiency of the process.

Two ore samples were tested, the first one grading at 8.16% K_2O and the second at 10.43% H_2O. The work with the low grade sample was terminated after a few preliminary tests when it was found that a grade of 10% K_2O could be obtained on a continuous basis by close control of the dense-medium plant. It was stated that a minimum value of 10% K_2O was needed for a commercially viable sample

Tests on the low grade sample indictaed that a concentrate grading at 10% K_2O could be obtained at about 80% K_2O recovery using an amine collector. On the high grade sample the grade could be raised to over 12% K_2O but at recoveries as low as 60%.

Providing that the dense-medium circuit can be controlled to give a feldspar reject value of better than 10% K_2O the flotation process will not be needed.

Drying the feldspar flotation concentrate resulted in a product marginally darker than freshly ground, untreated, feldspar rock. Raising the temperature of the concentrate to 900°C (1640°F) improved the whiteness. Untreated feldspar is extremely white when ground to -37 micrometres particle size.

Natural feldspar contains around 0.02% Fe_2O_3 but this can be reduced to 0.015% using High Intensity Magnetic separation. Grab samples show a Rubidium (Rb_2O) content generally between 1.5 and 2.0%.

Product Sizing

The sizing of the product taken directly from the dense-medium circuit is detailed in Table 7. During January 1987 the crushing size was changed to a passing mesh of 1/2" as a means of reducing the fines ahead of the dense-medium circuit. Size analysis of this latter sample is also shown in Table 7.

The ore samples were pulverised through 10 mesh (1.65mm) and samples split out for grinding. Grinding tests were carried out on Sample I in order to determine the optimum particle size for the best flotation efficiency. A standard grinding time of 35 minutes was used for the majority of the tests. The grinding test results are included in Table 8.

Samples I and II were ground and size analysed. Assays were carried out on the size fractions and are detailed in Table 9. The fact that the Li_2O minerals are harder than the feldspar is evident.

TABLE 7

FELDSPAR PROJECT EX DENSE MEDIUM PLANT

SAMPLE I Collected July 1986 (3/8" Passing Size ex Crushing Plant)			SAMPLE II Collected January 1987 1/2" Passing Size ex Crushing Plant)		
Mesh (Micrometres)	Wt.%	Cum.Wt.%	Mesh (Micrometres)	Wt.%	Cum.Wt.%
4750	28.24	28.24	4750	62.31	62.31
3360	15.76	44.00	3360	11.27	73.58
2380	12.79	56.79	2380	7.83	81.41
1680	12.44	69.23	1680	6.98	88.39
1190	9.35	78.58	1190	4.73	93.12
850	9.32	87.90	850	4.01	97.13
590	7.60	95.50	590	2.31	99.44
425	4.12	99.62	425	0.48	99.92
-425	0.38	100.00	-425	0.08	100.00

TABLE 8

GRINDING TESTS (SAMPLE TAKEN JULY 1986)

Mesh Micrometres)	GRINDING TIME 20 Minute		25 Minute		30 Minute		35 Minute	
	Wt.%	Cum.Wt.% Retained	Wt.%	Cum.Wt.% Retained	Wt.%	Cum.Wt.% Retained	Wt.%	Cum.Wt.% Retained
412	30.81	30.81	24.72	24.72	14.71	14.71	11.56	11.56
300	10.75	41.56	10.07	34.79	11.36	26.07	9.25	20.81
212	8.34	49.90	8.71	43.50	8.76	34.83	8.22	29.03
150	9.25	59.15	10.42	53.92	10.64	45.47	10.90	39.93
105	8.17	67.32	8.66	62.58	9.34	54.81	10.08	50.01
75	10.19	77.51	10.29	72.87	12.93	67.74	13.94	63.95
-75	22.49		27.13		32.26		36.05	

TABLE 9

SIZE/ASSAY DISTRIBUTIONS OF FEED SAMPLES I AND II

35 MINUTE GRIND

SAMPLE I

Mesh Micrometres	Wt.% Retained	Cum.Wt.% Retained	Grade % Li2O	Grade % Na2O	Grade % K2O	Cum. Dist. % Li2O	Cum. Dist. % Na2O	Cum. Dist. % K2O
425	3.90	3.90	0.46	1.87	9.74	7.93	2.91	4.47
300	4.09	7.99	0.42	1.97	8.24	15.53	6.13	8.44
212	7.56	15.55	0.33	2.12	7.62	26.56	12.53	15.22
150	13.18	28.73	0.24	2.34	7.62	40.54	24.85	27.04
105	10.83	39.56	0.22	2.51	7.99	51.08	35.70	37.22
75	10.17	49.73	0.20	2.61	8.12	60.07	46.30	46.94
-75	50.27	100.00	0.18	2.68	8.99	100.00	100.00	100.00
Feed	100.00		0.23	2.50	8.50			

SAMPLE II

Mesh Micrometres	Wt.% Retained	Cum.Wt.% Retained	Grade % Li2O	Grade % Na2O	Grade % K2O	Cum. Dist. % Li2O	Cum. Dist. % Na2O	Cum. Dist. % K2O
425	15.22	15.22	0.63	1.52	11.24	26.77	12.82	16.09
300	4.09	19.31	0.74	1.50	10.24	35.22	16.22	20.03
212	4.34	23.65	0.57	1.58	10.24	42.13	20.02	24.21
150	8.61	32.26	0.44	1.72	10.05	52.70	28.22	32.35
105	8.78	41.04	0.33	1.84	10.30	60.78	37.17	40.85
75	9.79	50.83	0.33	1.89	10.30	69.80	47.42	50.33
-75	49.17	100.00	0.22	1.93	10.74	100.00	100.00	100.00
Feed	100.00							

Samples

The testwork was performed on two samples of feldspar taken from the dense-medium section of the plant. These bulk samples were taken over a period of several days and so were considered representative of that period but the first sample, taken in July 1986, returned a lower K_2O content that that currently being produced (December 1986). This latter figure is considered more representative of plant operation and, since it contains greater than 10% K_2O, is better than the minimum specification level for some grades of commercial feldspar.

The samples conformed to the chemical analysis detailed below.

	Li_2O	Na_2O	K_2O
Sample I (July 1986)	0.26	2.51	8.16
Sample II (December 1986)	0.36	1.75	10.43

The samples were pulverised so that all material passed through a 10 mesh (1.65mm) screen before grinding.

Neither Fe_2O_3 nor P_2O_5 were routinely analysed in any of the tests. The pulverising stage introduces iron into the sample so that any analyses would have been misleading.

General Flotation Procedure

The test procedure was fairly straightforward. Ore was ground in the ceramic mill and the product then transferred to a 2.5 litre flotation cell. The reagent was added and conditioned, in most cases, for ten minutes. pH in all tests was adjusted to 2.4, before flotation, with sulphuric acid. In the majority of cases three or four concentrates were removed with a stage addition of collector before each one. No cleaning cycles were carried out on any of the tests. The batch grinding process invariably resulted in some material sized at 300 micrometres or coarser and this oversize could not be eliminated in a batch grind without producing an inordinately large amount of fines. Since it seemed unlikely that any recovery of particles greater than 300 micrometres occurred in any of the tests it became practice to screen the flotation tailings and report the analysis of both plus and minus 300 micrometre fractions. It was felt that the -300 micrometres fraction would give a better indication of the grade that would be achieved in a continuous grinding situation. Only in one case (Test 8) was the grinding prolonged in order to remove all of the +300 micrometres material.

Reagents

The three reagents used in this work were all produced by subsidiaries of Ak30 Chemie, America. They are identified below:

Armac T - A tallowamine acetate which is a firm paste room temperature. This cationic reagent was water soluble to the extent of about 5% at 60°C.

Duomeen T.D.O. - N-tallow-1, 3 - diaminipropane dioleate is a brown, viscous liquid at room temperature. It is stated to be insoluble at ambient temperature but is in fact soluble to the extent of 0.5% in water, to which has been added a few grams of NaOH, at about 80°C. It's high viscosity and low solubility would make the reagent difficult to use.

Duomac L11 - A primary beta-amine. The reagent was very soluble and was used as a 5% solution. It is understood that the product is no longer commercially available.

The reagent Duomeen TDO exhibited encouraging flotation properties but was found exceedingly difficult to dissolve. It did, however, form an emulsion which gave the appearnace of being a uniform product but the reagent was found to coalesce in large globules upon standing. Tests 1 and 2, which were exploratory ones, were undoubtedly affected by this phenomenon and the results should be treated with reserve.

Armac T and Duomac L11 dissolved in water satisfactorily and the total addition rate varied between 2000 and 2500 grams per tonne of feed.

Results and Discussion

Tests 1 to 5 were carried out using Sample No. I which was collected during July 1986.

The first three of these tests employed Duomeen TDO as the collector at a total addition rate of up to 3000 grams/tonne. No conditioning was carried out in the first test but, due to the poor results, the second test, and all subsequent tests, were conditioned for 10 minutes with the primary collector addition and for 2 minutes with all other staged reagent additions. As noted earlier, the dissolution of Duomeen TDO proved extemely difficult and it is likely that the results for both Tests 1 and 2 are strongly influenced by this fact. It should also be noted that the low solubility of TDO (0.5%), which in any event can only be achieved in hot water with added NaOH, would make a required addition rate of +/-2000 g/tonne on a plant scale extremely difficult to accomplish due to the huge volume of solution that would need to be prepared. It is unfortunate that Duomeen TDO is a very viscous liquid and would not lend itself to being metered, by any of the conventional reagent feeders, without dilution. Following the classical systems for feldspar flotation all work was carried out at a pH of 2.4, adjusted with sulphuric acid. Reagents were stage added as required - test details are given in Appendix I.

All products were assayed for Li_2O, Na_2O, and K_2O but it was decided to use the K_2O values as a measure of the efficiency of the upgrading process.

It was found that when using Duomeen TDO it was possible to achieve almost complete recovery of K_2O but only to a very low grade concentrate. In Test 3 for example the cumulative K_2O recovery could be as high as 99.26% but at an E.R. of 1.05. Assuming that 10% K_2O was the minimum concentrate grade requirement then only Concentrate I would be suitable and recovery would only be 76%.

Even though the problems that were noted with reagent solubility make the results difficult to interpret the conclusion is that to raise the K_2O grade, of Sample No. 1, from 8.16% to 10% (E.R. approx. 1.23) an overall recovery of no better than 80% can be predicted. The recovery of Soda-feldspar can be expected to be about 10% less than that for K_2O. Only about 40% of the Li_2O would report to the feldspar concentrate. Test results are shown in Table 10.

Tests 4 and 5 were conducted using two tallow amine acetates Armac T and Duomeen L11. The maufacturers representative had explained that these two reagents gave a superior performance to Duomeen TDO and were also easily water soluble. However, it was also stated that HF must be added ahead of the collector as it greatly accentuates the selectivity between the feldspar and quartz. In practice, concentrated HF was added to the pulp and conditioned for 10 minutes before the collector addition. Results are detailed in Table 10.

TABLE 10

DATA FROM FLOTATION TESTS 1 - 5

Test No. 1

Product	Cum.Wt.%	Cum. Cons. Grade (%)			Cum. Dist. (%)		
		Li2O	Na2O	K2O	Li2O	Na2O	K2O
Cons. 1	14.28	0.17	1.39	12.40	8.77	8.30	22.20
Cons. 2	28.33	0.17	1.80	11.75	17.40	21.30	41.72
Cons. 3	45.76	0.17	2.29	10.89	28.08	43.85	62.48
Cons. 4	63.57	0.20	2.62	10.13	43.49	69.80	80.77

Test No. 2

Product	Cum.Wt.%	Cum. Cons. Grade (%)			Cum. Dist. (%)		
		Li2O	Na2O	K2O	Li2O	Na2O	K2O
Cons. 1	42.58	0.17	1.39	12.40	28.00	35.73	59.22
Cons. 2	63.69	0.17	2.72	10.32	41.88	67.30	81.25
Cons. 3	76.72	0.20	2.90	9.65	59.51	86.43	91.50
Cons. 4	84.84	0.23	2.87	9.09	75.21	94.73	95.30
Cons. 5	87.39	0.24	2.84	8.89	80.16	96.40	96.07

Test No. 3

Product	Cum.Wt.%	Cum. Cons. Grade (%)			Cum. Dist. (%)		
		Li2O	Na2O	K2O	Li2O	Na2O	K2O
Cons. 1	60.57	0.17	2.84	9.97	40.94	65.31	76.67
Cons. 2	78.81	0.20	2.92	9.35	61.25	87.26	93.67
Cons. 3	87.20	0.23	2.90	8.88	80.25	95.86	98.36
Cons. 4	91.32	0.24	2.82	8.56	88.44	97.86	99.26

TABLE 10 (Continued)

Test No. 4

Product	Cum.Wt.%	Cum. Cons. Grade (%)			Cum. Dist. (%)		
		Li2O	Na2O	K2O	Li2O	Na2O	K2O
Cons. 1	47.37	0.29	3.17	9.44	55.45	60.61	53.68
Cons. 2	63.01	0.27	3.06	9.50	70.58	77.72	71.87
Cons. 3	66.81	0.27	3.01	9.52	73.65	81.31	76.32
Cons. 4	68.37	0.27	2.98	9.45	74.34	82.20	77.59

Test No. 5

Product	Cum.Wt.%	Cum. Cons. Grade (%)			Cum. Dist. (%)		
		Li2O	Na2O	K2O	Li2O	Na2O	K2O
Cons. 1	17.94	0.49	2.65	9.50	35.34	19.05	20.03
Cons. 2	22.02	0.46	2.69	9.57	40.41	23.76	24.76
Cons. 3	38.18	0.36	2.87	9.78	56.01	43.84	43.87
Cons. 4	46.00	0.34	2.92	9.85	62.28	53.77	53.24

Contrary to expectations, neither L11 or Armac T performed as well as expected. Test 4 using L11 resulted in a voluminous, uncontrollable froth that would be exceedingly difficult to handle on a plant scale. Total K_2O recovery from Test 4 was, at 77.59%, as good as that achieved after one stage for Duomeen TDO (Test 3). It follows, therefore, that from the point of view of flotation time reagent L11 is inferior to Duomeen TDO. Another curious effect with L11 was that the minerals had ceased to float after eight minutes and, in spite of the addition of extra reagent, no further recovery of K_2O was achieved.

Test 5, using Armac T as the collector, also gave poor results achieving an overall recovery of K_2O of only 53.24% at a much lower enrichment than that achieved with Duomeen TDO, for an equivalent recovery. It was noted that, unlike Duomeen TDO, both L11 and Armac T floated the Li_2O minerals at least as well as K_2O - at the same time these reagents gave a better Na_2O recovery than Duomeen TDO. Surprisinly the HF did not improve selectivity but did appear, in this test, to concentrate the Li_2O minerals.

Tests 7 to 10 were carried out on a feldspar composite grading at over 10% K_2O and deemed to be more representative of plant operation at the time (December 1986).

The material was ground in the same manner as for the previous sample with the exception of Test 8 where grinding was carried out for 60 minutes to eliminate all of the +300 micrometres fraction. The data for each test is appended and the results summarised in Table 11.

The effect of grinding time on flotation was examined by simply comparing a standard 35 minute grind to one of 60 minutes, which had the effect of removing all of the +300 micrometres oversize.

Results indicate a slightly better enrichment of K_2O with the finer grind - it is probable that a further stage was needed to bring the overall recovery up from the value of 82.96, that was achieved, up to approximately 90%. None the less that primary concentrate, at 12.55% K_2O, was very close to the theoretical maximum value for Tanco feldspar. It was also noted that finer grinding increased the selectivity against Li_2O, although this would be of doubtful benefit, unless the Li_2O could be recovered, which is highly improbable.

Tests 7 and 9 were carried out under similar conditions but using the second feldspar sample. It was again demonstrated that a high recovery of K_2O could be achieved but at the expense of the K_2O grade. The best E.R. obtained was 1.16 for the primary concentrate in Test 9 - this was, however, achieved at an unacceptably low K_2O recovery of 64.25%.

Overall it can be assumed that a recovery of around 90% of the K_2O can be achieved by flotation using Duomeen TDO as the collector - the grade of the K_2O would be raised by no more than 1% K_2O in single stage flotation.

TABLE 11

DATE FROM FLOTATION TESTS 7 - 10

Test No. 7

Product	Cum.Wt.%	Cum. Cons. Grade (%)			Cum. Dist. (%)		
		Li2O	Na2O	K2O	Li2O	Na2O	K2O
Cons. 1	67.57	0.18	1.89	11.51	33.70	71.58	74.68
Cons. 2	83.46	0.23	1.87	10.90	53.97	87.70	87.37

Test No. 8

Product	Cum.Wt.%	Cum. Cons. Grade (%)			Cum. Dist. (%)		
		Li2O	Na2O	K2O	Li2O	Na2O	K2O
Cons. 1	41.63	0.15	1.28	12.55	17.70	29.92	50.88
Cons. 2	72.10	0.18	1.72	11.81	36.70	63.61	82.96

Test No. 9

Product	Cum.Wt.%	Cum. Cons. Grade (%)			Cum. Dist. (%)		
		Li2O	Na2O	K2O	Li2O	Na2O	K2O
Cons. 1	55.36	0.17	1.58	12.05	25.30	51.26	64.25
Cons. 2	82.45	0.22	1.77	11.37	49.33	85.39	90.31
Cons. 3	92.37	0.28	1.78	10.92	68.52	96.55	97.11

Test No. 10

Product	Cum.Wt.%	Cum. Cons. Grade (%)			Cum. Dist. (%)		
		Li2O	Na2O	K2O	Li2O	Na2O	K2O
Cons. 1	43.64	0.24	1.65	12.42	28.16	41.71	50.86
Cons. 2	60.94	0.25	1.73	12.09	40.26	61.05	69.11
Cons. 3	69.13	0.25	1.77	11.94	46.88	71.06	77.46

The magnetic fraction from the feed to Test 9 was removed and found to be 0.18%. The presence of free iron made no perceptable difference to the flotation performance.

Having accepted that it was possible to produce a feldspar containing greater than 10% K_2O directly from the plant the testwork was prematurely terminated without any cleaner tests having been carried out. It is probable that a 12.5% K_2O concentrate could be produced from a feed grading 10.0% K_2O but the losses incurred would almost certainly make cleaning a costly, and probably unnecessary exercise. In any event, a value of 12.5% K_2O is very close to the maximum theoretical value for K-feldspar at Tanco.

Test 10 was performed to re-evaluate the Armac T reagent but without the use of HF. The procedure was as used throughout the work.

The test was not totally satisfactory since flotation ceased after 10 1/2 minutes total flotation time with the overall K_2O recovery at 77.46%. The cumulative grade, however, was quite good at 11.94% K_2O.

The test demonstrated that Armac T gives a better recovery and grade without the use of HF.

Product Colour

It is understood that for some commercial applications the colour of the feldspar is of great importance. A set of samples was, therefore, assembled as detailed below.

(i) Feldspar from plant. Crushed and Ceramic Ground -37 micrometres fraction.
(ii) Feldspar from plant. Crushed and Ceramic Ground -75 +37 micrometeres fraction.
(iii) Feldspar from plant. Crushed and Ceramic Ground -105 +75 micrometres fraction.
(iv) Feldspar from plant. Crushed and Ceramic Ground -37 micrometeres fraction heated to 900°C.
(v) High grade feldspar flotation cons. - residual iron from pulverizing present.
(vi) High grade feldspar flotation cons. - as (v) but heated to 900°C.
(vii) High grade feldspar flotation cons. - Magnetic iron removed.
(viii) High grade feldspar flotation cons. - As (vii) but heated to 900°C.

Feldspar reject from the dense medium plant is, commonly, grey in colour although it may vary depending upon the quantity of soda-feldspar present. Orange or brown feldspar is not unusual but rarely present in large quantities.

When ground finer that 37 micrometres the Tanco feldspar is pure white in colour and would seem to meet the requirements for use as a filler. Size fractions coarser than 37 micrometres get progressively darker in colour as the particle size increases - the coarsest product that would be commercially produced for ceramics, say -74 micrometres (200 mesh), was not so discoloured as to make it unacceptable.

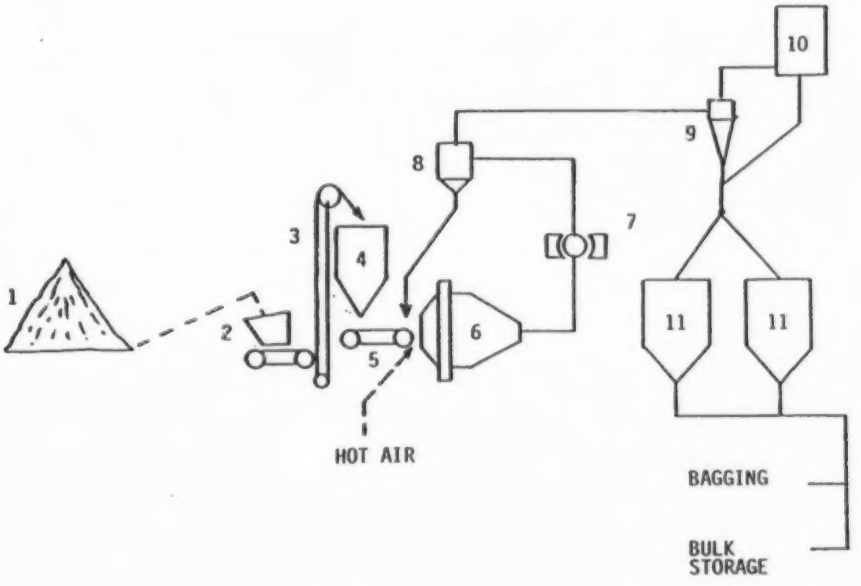
The -37 micrometres was heated to 900°C (1640°F) which is about 100°C below the point at which it starts to frit. No colour change was noticed

The flotation concentrate produced when using Duomeen TDO collector was noticeably darker than untreated ground feldspar. The colour could make this product unacceptable for use as a filler, however, it must be noted that the concentrate is of mixed size range and, hence, the colour of "filler product", which would be -10 micrometres, is really unknown. Heating of this material to 900°C (1640°F) tended to whiten it. The presence of about 0.2% residual pulverizing iron did not alter the colour in any way.

CONCLUSIONS AND RECOMMENDATIONS

Improvements to operation of the existing heavy medium separation plant will enable the reject to grade, on average, in excess of 10% K_2O. Whilst flotation of the ground feldspar would enable this grade to be increased close to 12% K_2O, there is little evidence from the marketplace that such a material would fetch a premium in price. Furthermore, as the circuity would be inevitably much more complex to construct and operate and the loss of product would be significant, no further processing is warranted.

It is recommended, therefore, that the simplest approach is also the best and a simple dry grinding plant of stockpiled feldspar is all that is required to achieve a marketable product. Figure 4 indicates the likely flowsheet required.



1 Stockpile	2 Feed Hopper	3 Bucket Elevator
4 Surge Bin	5 Feed Conveyor	6 Pebble Mill
7 Magnet	8 Classifier	9 Cyclone
10 Baghouse	11 Product Bins	

Figure 4 Possible flowsheet for feldspar production

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APPENDIX

FELDSPAR TEST 1

Ground 750 g. Feldspar for 35 minutes in the Ceramic Mill. Placed in flotation cell and added 25 ml. of 2% Duomeen TDO. No conditioning.

Product	Wt.%	Grade (%)			Distribution (%)		
		Li_2O	Na_2O	K_2O	Li_2O	Na_2O	K_2O
Cons. 1	14.28	0.17	1.39	12.40	8.77	8.30	22.20
Cons. 2	14.05	0.17	2.21	11.08	8.63	13.00	19.52
Cons. 3	17.43	0.17	3.09	9.45	10.68	22.55	20.76
Cons. 4	17.81	0.24	3.48	8.19	15.41	25.95	18.29
Tailings	36.43	0.43	1.98	4.21	56.51	30.20	19.23
Feed	100.00	0.27	2.39	7.98	100.00	100.00	100.00

Reagents 25 ml of 2% Duomeen TDO to Cons. 1
10 ml of 2% Duomeen TDO to Cons. 2
10 ml of 2% Duomeen TDO to Cons. 3
10 ml of 2% Duomeen TDO to Cons. 4

Reagents did not dissolve well hence additional rate impossible to calculate.

Time 4 Mins. pH 2.4 throughout with H_2SO_4
4 Mins.
3 1/2 Mins.
3 1/2 Mins.

FELDSPAR TEST 2

Ground 750 g. Feldspar for 35 minutes in the Ceramic Mill. Placed in flotation cell and added 50 ml. of 2% Duomeen TDO. Conditioned 10 minutes.

Product	Wt.%	Grade (%)			Distribution (%)		
		Li2O	Na2O	K2O	Li2O	Na2O	K2O
Cons. 1	42.58	0.17	2.16	11.25	28.00	35.73	59.22
Cons. 2	21.11	0.17	3.85	8.44	13.88	31.57	22.03
Cons. 3	13.03	0.35	3.78	6.36	17.63	19.13	10.25
Cons. 4	8.12	0.50	2.63	3.79	15.70	8.30	3.80
Cons. 5	2.55	0.50	1.69	2.45	4.95	1.67	0.77
Tailings +300	3.49	0.66	1.89	8.13	8.89	2.56	3.51
-300	9.12	0.31	0.29	0.37	10.95	1.04	0.42
Feed	100.00	0.26	2.57	8.09	100.00	100.00	100.00

Reagents 50 ml of 2% Duomeen TDO to Cons. 1 Time 3 1/2 Mins.
20 ml of 2% Duomeen TDO to Cons. 2 Time 3 1/2 "
20 ml of 2% Duomeen TDO to Cons. 3 Time 2 1/2 "
20 ml of 2% Duomeen TDO to Cons. 4 Time 1 1/2 "
10 ml of 2% Duomeen TDO to Cons. 5 Time 1 "

Reagents did not dissolve well hence additional rate impossible to calculate.

pH 2.4 throughout with H_2SO_4

FELDSPAR TEST 3

Ground 750 g. Feldspar for 35 minutes in the Ceramic Mill. Placed in flotation cell and added 100 ml. of 1% Duomeen TDO. Reagent still not completely dissolved. Conditioned for 10 minutes.

Product	Wt.%	Grade (%)			Distribution (%)		
		Li2O	Na2O	K2O	Li2O	Na2O	K2O
Cons. 1	60.57	0.17	2.84	9.97	40.94	65.31	76.67
Cons. 2	18.24	0.28	3.17	7.34	20.31	21.95	17.00
Cons. 3	8.39	0.57	2.70	4.40	19.00	8.60	4.69
Cons. 4	4.12	0.50	1.28	1.71	8.19	2.00	0.90
Tailings +300	2.81	0.68	1.82	7.70	7.59	1.94	0.61
-300	5.87	0.17	0.09	0.18	3.97	0.20	0.13
Feed	100.00	0.25	2.63	7.88	100.00	100.00	100.00

Reagents 100 ml of 1% Duomeen TDO to Cons. 1 Time 4 Mins.
40 ml of 1% Duomeen TDO to Cons. 2 Time 2 1/2 Mins.
20 ml of 1% Duomeen TDO to Cons. 3 Time 2 Mins.
20 ml of 1% Duomeen TDO to Cons. 4 Time 1 Min.

Reagents disolved better at 1% solution plus NaOH. pH 2.4 throughout with H_2SO_4

FELDSPAR TEST 4

Ground 750 g. Feldspar for 35 minutes in the Ceramic Mill. Placed in flotation cell and Conditioned for 10 minutes with 1 ml Conc. HF. Added 20 ml. of 5% Lil and conditioned further 10 minutes. Adjusted pH to 2.4 with H_2SO_4.

Product	Wt.%	Grade (%)			Distribution (%)		
		Li2O	Na2O	K2O	Li2O	Na2O	K2O
Cons. 1	47.37	0.29	3.17	9.44	55.45	60.61	53.68
Cons. 2	15.64	0.24	2.71	9.69	15.13	17.11	18.19
Cons. 3	3.80	0.20	2.34	9.75	3.07	3.59	4.45
Cons. 4	1.56	0.11	1.41	6.77	0.69	0.89	1.27
Tailings +300	7.77	0.42	1.90	8.76	13.16	5.96	8.17
-300	23.86	0.13	1.23	4.97	12.50	11.84	14.24
Feed	100.00	0.25	2.48	8.33	100.00	100.00	100.00

Reagent 20 ml of 5% L 11 to Cons. 1. Time 3 Mins.
10 ml of 5% L 11 to Cons. 4 Time 3 "
Time 2 "
Time 2 "

Very strong uncontrollable froth in Cons. 1-3

FELDSPAR TEST 5

Ground 750 g. Feldspar for 35 minutes in the Ceramic Mill. Placed in flotation cell and conditioned for 10 minutes with 1 ml Conc. HF. Added 100 ml. of 1% Armac T and conditioned for 10 minutes. Adjusted pH to 2.4 with H_2SO_4.

Product	Wt.%	Grade (%)			Distribution (%)		
		Li2O	Na2O	K2O	Li2O	Na2O	K2O
Cons. 1	17.94	0.49	2.65	9.50	35.34	19.05	20.03
Cons. 2	4.08	0.31	2.88	9.87	5.07	4.71	4.73
Cons. 3	16.16	0.24	3.10	10.06	15.60	20.08	19.11
Cons. 4	7.82	0.20	3.17	10.19	6.27	9.93	9.37
Tailings +300	8.51	0.40	1.88	8.82	13.67	6.41	8.82
-300	45.99	0.13	2.16	7.02	24.05	39.82	37.94
Feed	100.00	0.25	2.50	8.51	100.00	100.00	100.00

Reagent 100 ml of 1% Armac T to Cons. 1 Time 6 Mins.
50 ml of 1% Armac T to Cons. 3 Time 2 "
20 ml of 1% Armac T to Cons. 4 Time 2 "
Time 3 "

pH controlled at 2.4 with H_2SO_4

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FELDSPAR TEST 1 (New Sample)

Ground 750 g. Feldspar for 35 minutes in the Ceramic Mill. Added 200 ml 0.5% Ducmeen TDO. Dissolved satisfactorily at 0.5% + NaOH. Conditioned 10 minutes.

Product	Wt.%	Grade (%)			Distribution (%)		
		Li2O	Na2O	K2O	Li2O	Na2O	K2O
Cons. 1	67.57	0.18	1.89	11.51	33.70	71.58	74.68
Cons. 2	15.89	0.46	1.81	8.32	20.27	16.12	12.69
Tailings +300	10.63	0.80	1.48	10.43	23.57	8.82	10.65
-300	5.91	1.37	1.05	3.48	22.46	3.48	1.98
Feed	100.00	0.36	1.78	10.41	100.00	100.00	100.00

Reagent 200 ml of 0.5% Duomeen TDO to Cons. 1
80 ml of 0.5% Duomeen TDO to Cons. 2

Times 4 Mins.
3 Mins.

pH maintained at 2.4 with H_2SO_4

FELDSPAR TEST 8

Ground 750 g. Feldspar Sample II for 60 minutes in the Ceramic Mill. Added 200 ml 0.5% Ducmeen TDO. Conditioned 10 minutes.

Product	Wt.%	Grade (%)			Distribution (%)		
		Li2O	Na2O	K2O	Li2O	Na2O	K2O
Cons. 1	41.63	0.15	1.28	12.55	17.70	29.92	50.88
Cons. 2	30.47	0.22	2.32	10.81	19.00	33.69	32.08
Tailings	27.90	0.80	1.94	6.27	63.30	30.39	17.04
Feed	100.00	0.35	1.78	10.27	100.00	100.00	100.00

Reagent 200 ml of 0.5% Duomeen TDO to Cons. 1
80 ml of 0.5% Duomeen TDO to Cons. 2

Times 4 Mins.
5 Mins.

pH controlled at 2.4 throughout

FELDSPAR TEST 9

Ground 750 g. Feldspar (Sample II) for 35 minutes in the Ceramic Mill. Placed in flotation cell and removed free iron with hand magnet. Added 200 ml. of 0.5% Duomeen TDO - Conditioned 10 minutes.

Product	Wt.%	Grade (%)			Distribution (%)		
		Li_2O	Na_2O	K_2O	Li_2O	Na_2O	K_2O
Cons. 1	55.36	0.17	1.58	12.05	25.30	51.26	64.25
Cons. 2	27.09	0.33	2.15	9.99	24.03	34.13	26.06
Cons. 3	9.92	0.72	1.92	7.12	19.19	11.16	6.80
Tailings +300	2.30	1.87	1.24	8.68	11.56	1.67	1.92
-300	5.33	1.39	0.57	1.87	19.92	1.78	0.97
Feed	100.00	0.37	1.71	10.38	100.00	100.00	100.00

Reagent 200 ml of 0.5% Duomeen TDO to Cons. 1
80 ml of 0.5% Duomeen TDO to Cons. 2
40 ml of 0.5% Duomeen TDO to Cons. 3

Time 4 Mins.
4 "
2 "

pH controlled at 2.4 throughout without H_2SO_4.

Magnetic iron 0.183%

FELDSPAR TEST 10

Ground 750 g Feldspar (Sample II) for 35 minutes in Ceramic Mill. Iron removed by magnet. Floated using 50 ml. Armac T (2%). Conditioned 10 minutes - pH adjusted to 2.4. NaOH not used as Armac T dissolved relatively easily in hot water. No HF.

Product	Wt.%	Grade (%)			Distribution (%)		
		Li_2O	Na_2O	K_2O	Li_2O	Na_2O	K_2O
Cons. 1	43.64	0.24	1.65	12.42	28.16	41.71	50.86
Cons. 2	17.30	0.26	1.93	11.24	12.10	19.34	18.25
Cons. 3	8.19	0.30	2.11	10.86	6.62	10.01	8.35
Tailings +300	3.90	1.33	1.33	9.80	13.96	3.01	3.59
-300	26.97	0.54	1.66	7.49	39.16	25.93	18.95
Feed	100.00	0.37	1.73	10.66	100.00	100.00	100.00

Reagent 50 ml of 2% Armac T to Cons. 1 Time 4 Mins.
25 ml of 2% Armac T to Cons. 2 Time 3 1/2 Mins.
12 ml of 2% Armac T to Cons. 3 Time 3 "

pH 2.4 throughout using H_2SO_4.